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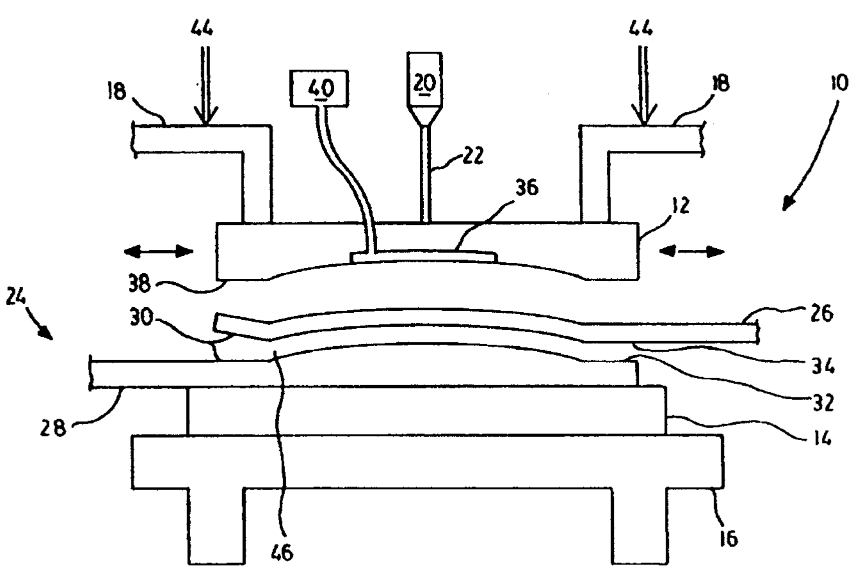

(57) Abstract

Plastic pieces for laser welding are clamped by a support mechanism that covers an interface of a joint to be welded. The support mechanism is transparent to the laser radiation. Surface cooling of the support mechanism and the pieces is provided by fluid such as nitrogen directed to the point of laser impingement at the interface. The local intensity of the laser can be reduced by beam splitting. Heating at the weld zone is controlled by the differing optical characteristics of the components. One of the pieces can be used as a waveguide to direct the laser radiation to the interface.

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METHOD OF CLAMPING THERMOPLASTIC PIECES AND HEAT CONTROL FOR LASER WELDING

FIELD OF INVENTION

The present invention relates to laser welding of plastics material.

BACKGROUND OF THE INVENTION

It is known that thermoplastic pieces may be welded by application of a laser. In the usual configuration, pieces are overlapped with a radiation transparent plastic as the upper piece, i.e. closest to the laser. The laser beam passes through this piece and is absorbed by the lower piece, which causes melting at the interface of the pieces and upon cooling the pieces are welded to one another.

A requirement of laser welding is that the surfaces must have intimate contact. Gaps greater than 150 micrometers can result in weld faults such as air bubbles, thus producing non-hermetic welds. However, achieving intimate contact between two plastic pieces is difficult due to such factors as surface irregularities, thermo stresses on the pieces, and piece deformation after injection molding. To circumvent these problems, clamping must be used to push the mating surfaces together into intimate contact. This however, has the adverse effect of blocking laser beam access to the interface.

Most clamps are made from metal and are molded to fit the part, as in vibration or ultrasonic welding. With laser beam welding these types of clamps do not allow the laser beam to access the interface. Therefore to provide access to the interface, the clamps are positioned at spaced locations. However, effective clamping of plastic pieces is difficult since plastic pieces are often three-dimensional and the mating surfaces follow a three dimensional contour. Ensuring that the mating surfaces have intimate contact often requires the clamp apparatus to apply pressure directly to the interface, and therefore impedes access to the interface.

Moreover, even where sufficient clamping can be achieved, the preferred material properties, i.e. transmission of greater than 50% of a radiation transparent upper piece and an absorption of greater than 50% fully radiation absorbent lower piece, for laser welding of plastic, are not always possible. In some situations the optical characteristics of the upper and lower pieces produce surface heating and melting or heating at locations other than that of the intended weld. Plastic deformation of components and possible vaporizing of material could also occur.

It is therefore an objective of the present invention to provide the components and method of a clamping apparatus and weld assembly that will obviate or mitigate the above disadvantages. SUMMARY OF THE INVENTION

In one aspect of the invention, clamping blocks are formed from a highly transparent plastic, so that a laser beam can penetrate through the clamp apparatus to the plastic pieces to be welded. Since the plastic pieces are overlapped and the top piece is transparent to laser radiation, melting or material softening occurs in the clamping block and the upper plastic piece is inhibited. Pigments and dyes, either absorbent or transparent to the laser, may be used in the plastic pieces to control the degree and location of localized heating. Impact modifiers may also be added to the plastic to generate localized heating and alter the physical characteristics of the plastic material.

The clamping blocks may be molded from acrylic, which is a hard, highly transparent plastic. In the preferred embodiment a clamping apparatus is designed to conform to the surface of the plastic pieces so that the entire interface between the pieces is kept under pressure and in intimate contact. Preferably the thickness of the clamping apparatus, situated over the interface, is kept constant so that a laser beam always travels through the same depth of plastic material to reach the interface. This reduces energy losses from having a laser beam travel through thicker sections of the clamp apparatus, which could vary the intensity of the beam at the interface. In addition, the radius of curvature of the block surfaces may be kept the same at both the outer and inner surfaces of each block. This minimizes lensing affects, which can change the focal position of the laser beam.

In a preferred embodiment, at least one channel is provided in the bottom of the overlying clamp. For cooling purposes of the upper piece, a column of air or any other suitable medium is directed along the channel during welding. The channel is preferably located where the laser beam impinges on the upper piece, where localized cooling is desired.

As an alternative for semi transparent upper pieces, the cooling medium may be supplied to the surface of the overlying block by a vortex tube attached to the head of the laser. The vortex tube can also be used to supply a clamping force to the weldable pieces, supported by a frame.

In another aspect of the invention, both the upper and lower plastic pieces are transparent to the laser beam. For this application localized heating is initiated at the interface by an absorbent material. This material may apply to the interface in the form of a spray or film.

In a further aspect of the invention a gasket is attached directly, by laser welding, to a plastic piece, thereby reducing the need for adhesive and the potential for seal damage. The attachment of a gasket to a plastic component inhibits movement of the gasket during assembly of a connection. The gasket is preferably made of an elastomeric material.

In an additional aspect of the invention, the laser beam is split into two or more less intense beams. These beams strike the upper plastic piece at different locations, but are angled in such a way so as to converge at the interface. This provides the necessary laser intensity at the desired weld location but distributes the beam intensity in the upper piece, in order to limit situations in which undesirable diffuse heating of the upper piece may occur.

In a further aspect a wave guide effect of the upper piece may be used to direct the laser beam to the interface. The laser beam may be focused on one end of the piece and due to the higher index of refraction of the piece over that of a surrounding medium, the beam can experience total internal reflection as it propagates down the piece to the interface.

A still further aspect of this invention is where the upper part is generally absorbent to the laser beam. In this situation, apertures are formed in the top piece in order to facilitate access of the laser beam to the interface.

In a further aspect of the invention, a method of welding hollow plastic pieces to enhance the resistance of the natural tendency of a clamped hollow plastic part to buckle is provided. This aspect includes the step of connecting a pressure device to the hollow piece and modulating the interior pressure by controlling the supply of a medium to the interior of the piece. Controlling the pressure of the interior helps to maintain the structural integrity of the hollow piece and minimize the potential gap between the pieces at the interface, during the welding process.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention will now be described by way of example only with reference to the accompanying drawings, in which

Figure 1 is a cross-sectional view of the clamping apparatus.

Figure 2 is a view of the apparatus of Figure 1 with the components clamped.

Figure 3 shows an alternative clamping arrangement for a hollow part.

Figure 4 shows a further arrangement of a clamp.

Figure 5 shows a clamping arrangement for welding absorbent materials.

Figure 6 shows a welding arrangement for multiple beams.

Figure 7 shows an arrangement for effecting spot welding of two components.

Figure 8 is a view similar to Figure 1 with provision for surface cooling.

Figure 9 is a view of an alternative embodiment of surface cooling.

Figure 10 is a sectional view of two components being welded.

Figure 11 is a further aspect of Figure 10.

Figure 12 is a schematic illustration of a control system for the laser welding head.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring therefore to Figure 1, a clamping apparatus 10 comprises an overlying clamping block 12, made of a highly transparent and hard plastic material and an underlying clamping block 14. The underlying block 14 rests on a support 16. The overlying block 12 is held by a clamping device 18 and is movable relative to the underlying block 12 between open and closed positions. The clamping apparatus 10 with the support 16 and the clamping device 18 are used as a support mechanism to hold a weldable assembly 24 in position during the welding process. A laser head 20 is positioned above the clamping apparatus 10 and propagates a laser beam 22 that impinges on the overlying clamping block 12. The beam 22 is moveable relative to the clamping block 12 along a weld line, either by movement of the laser head 20 or deflection of the beam 22. The opposed faces of the clamping blocks 12, 14 are shaped to be complementary to the particular contoured form of the weldable assembly 24. A thickness and radius of curvature of clamping block 12 is kept substantially constant, in order to minimize variability in the intensity and focus of the laser beam 22 transmitted to the interior of the clamping apparatus 10.

The weldable assembly 24 comprises two components 26, 28 to be welded to one another along an interface 30, defined between an opposing bottom surface 32 and a top surface 34. The surfaces 32, 34 are placed in abutment when the assembly 24 is positioned by the clamping apparatus 10. The plastic components 26, 28 of the assembly 24 are positioned between the blocks 12, 14 in an overlapping manner, with the upper component 26 greater than 50% transparent to the laser beam 22 (i.e. the beam is alternated less than 50% is passing through the component 26). In a preferred arrangement, the lower component 28 is absorbent to the radiation of the laser beam 22.

In the operation of the preferred embodiment, the blocks 12, 14 are movable from the open position of Figure 1 to a closed, or clamped, position of Figure 2 by operation of the clamping device 18. In the closed position the upper component 26, i.e. closest to the laser head 20, and the lower component 28 are located in the clamping apparatus 10 so that they partially overlap, with the surfaces 32, 34 held in intimate contact, or abutment, along the interface 30. The magnitude of a clamping force 44 is sufficient to conform the components 26, 28 to the shape of the blocks 12, 14. This reduces the potential variability in a gap width

46 between surfaces 32, 34, which may result from the manufacture of the plastic components 26, 28 and their subsequent handling. The clamping force 44 will depend upon the size and geometry of the components 26, 28 to be welded. In some cases, as with flat components, a force of 220 N is sufficient. For plastic components of a three-dimensional shape, a force greater than 446 N is typically necessary.

Referring to Figure 2, a channel 36 is formed in a bottom surface of the block 14 to provide a passageway for a cooling medium 40. The channel 36 is preferably in contact with a top surface of component 26, adjacent to a focal region 42 of the laser beam 22. This provides localized temperature control of both the block 12 and the component 26, in response to potential excessive heat generation by the laser beam 22.

During the welding process, the laser head 20 moves the laser beam 22 into position. The beam 22 radiation then penetrates through the transparent overlying block 12 and upper component 26 to the focal region 42, located at the interface 30. The beam 22 radiation is subsequently absorbed by the lower component 28 and localized heating occurs, which causes the surfaces 32, 34 to melt if the beam is of a sufficient intensity. The laser beam 22 is moved along the length of the interface 30 to progressively melt the plastic components 26, 28, which upon cooling are welded together. During the welding process the medium 40 is directed along the channel 36, in order to prevent diffuse heating, softening, and possible melting of the overlying block 12 and the main body of the upper component 26. When the welding process is completed, the clamping device 18 and the laser head 20 are retracted and the welded assembly 24 is removed from the clamping apparatus 10.

The components 26, 28 are composed of thermoplastic materials that typically have differing optical characteristics relative to the laser beam 22. The use of a Nd:YAG, or diode lasers have been found satisfactory, operating at wavelengths of 500 nm to 1060 nm. At these wavelengths, the blocks 12, 14 can be made of acrylic, polycarbonate or PMMA materials that are essentially transparent to these wavelengths. Where the materials of the block12 and the component 26 exhibit some attenuation of the laser beam 22, the cooling provided by the medium 40 inhibits degradation by maintaining the material below the melting point. The amount of cooling required depends upon how much absorbance of the laser beam 22 occurs in the materials of the block 12 and the component 26. In cases where the amount of absorbance in the material is approaching 50%, the medium 40 temperature should be less than 5 ^{0}C and the medium 40 pressure higher than 620 kPa. The use of chemically inert gases with the plastic materials used for the blocks 12, 14 and components 26, 28, such as nitrogen, prevents oxidation and charring of the materials should melting

occur. Oxidation can blacken the materials and increase their absorbance so that beam 22 energy is inhibited from penetrating to the interface 30.

In a further embodiment, shown in Figure 3, the clamping of a hollow component 52 requires a method to prevent the buckling of sidewalls 54, when the clamping force 44 is applied. A pressure device 56 can be connected to the component 52 and thereby increase the pressure of an interior 58 of component 52 by supplying a medium 60 to the interior 58. Typical gas pressures can range from 138 kPa to 620 kPa. Formation of the weld may be disturbed if gas 60 escapes through the gap 46 during welding. Escaping of the gas 60 can be inhibited by applying a sealant 61 in the gap 46 or the design of the gap can be such that the escape of the gas 60 is minimized.

The use of gas pressure 56 in hollow component 52 can also be used after welding to test the seal strength of the weld. Low pressure gas 60 can initially be used for the welding and once the weld cycle is complete the gas pressure 56 can be increased to test the weld for pinholes and other defects. This allows for in situ component testing during production. The amount of gas pressure 56 depends upon the shape of the hollow component 52, the rigidity of the material, and the magnitude of the clamping force 44. Controlling the pressure of the interior 58 helps to maintain the structural integrity of the hollow component 52, and minimize the potential gap 46 at the interface 30, during the welding process.

As shown in Figure 4 the clamping apparatus 10 may also be used where the upper component 26 and the lower component 28 are both generally transparent to the laser beam 22. In this case, an intermediate layer of material 62 substantially absorbent to the laser beam 22 is applied to the interface 30, in order to generate the localized heating required for welding. The layer 62 can be applied to the interface 30 in the form of a spray consisting of a liquid dye or pigment, a dye or a pigment paste printed on the interface 30, or a film or gasket of very thin material inserted between the upper component 26 and lower component 28. The film or gasket is absorbent, either inherently or by additional dyes or pigments, and can be materially compatible with each of the components 26, 28 to become part of the weld, if desired..

In a further application of this embodiment, a gasket 64, shown in Figure 4a, is attached directly by laser welding to a plastic component 50, which is held in the clamping apparatus 10 similar to the components 26, 28 of Figure 1. Laser welding of the gasket 64 reduces the need for adhesive and the potential for seal damage, as well as inhibiting movement of the gasket 64. The gasket 64 is typically made of an elastomeric material, which is laser weldable with the plastic component 50. The elastomeric material is typically

welded to hard thermoplastics such as Nylon, PET, or PBT, and the elastomeric material is intended to replace rubber material which cannot be welded and is typically glued.

Many applications in, but not limited to, the automotive industry, require a black colored components which are typically absorbent to laser radiation. A pigment or dye may be used in laser welding which is black in the visible spectrum but which is transparent to the radiation of the laser beam 22. This may be obtained by mixing pigments or dyes of the primary colors red, yellow and blue exhibiting transparency to the wavelength of the laser beam 22. Suitable pigments that have been used to provide a visible black color that is optically transparent at laser wavelengths are available from Ciba Geigy under the following brand names; blue - iragalite gbp, yellow - cromophtol 8gn, and red - iragalite 2bp. When mixed in the proportion of 1:1:0.5 (blue-yellow-red) a black color is obtained in the visible spectrum but high transmission is retained at the wavelength of the laser beam 22. Alternative pigments are; red - iragalite rubine 4bp, blue - cromophtol a3r, and yellow - iragalite wgp. Generally, pigments of primary colors exhibiting high transmission to laser wavelength but low transmission to the required visible wavelength may be mixed to obtain the requisite attributes and added to the polymer of the components to be welded. Colors of pigments or dyes other than black, such as red, may also be obtained by appropriate mixing.

In Figures 5a and 5b, an embodiment is shown where the upper component 26 and the lower component 28 are both generally absorbent to the laser beam 22. Apertures 72 can be formed in the upper component 26 to facilitate the access of the laser beam 22 to the interface 30, which is between oppositely directed surfaces between components 26 and 28. The apertures 72 can be any appropriate shape, such as but not limited to circular or rectangular.

In another embodiment shown in Figure 6, diffuse heating is mitigated by splitting of the laser beam 22 shown in Figure 1. The local intensity of the laser beam 22, impinging on the overlying block 12 and upper component 26, is reduced by splitting the beam 22 into two separate beams 66, by using a 50/50 beam splitter so that each beam 66 has half the power of the single beam 22. These separated beams 66 impinge the block 12 and component 26 at different locations, but the beams 66 are angled in such a way so as to converge at the interface 30 to provide the prerequisite power at the focal region 42. The angle 67 between the beams 66 and the surface of the overlaying block 12 is typically limited to greater than 15^0, in order to reduce reflection losses of the beam 22. Surface cooling, shown in Figures 2, 8, 9, and 10, can also be used in conjunction with the technique of beam splitting.

A further aspect of the apertures 72 for absorbent materials is shown in Figure 7a, which is suitable for spot and continuous welding applications. Each aperture 84 is smaller

than those in Figure 5, and the structures of the apertures 84 can be important to achieve a quality weld 86, shown in Figure 7b. Typically the apertures 84, located in component 26, are of a triangular or cone-like shaped cross-section, where a width 88 at a top 90 of the aperture 84 is commonly smaller than 2 mm. In order to achieve a weld 86 using the apertures 84, the laser beam 22 is initially focussed at the interface 30. As the material melts around the base 92 of the aperture 84, the beam 22 is defocused. The defocusing of the beam 22 melts more material further away from the interface 30 until the aperture 84 collapses on itself thus forming the weld 86 shown in Figure 7. This application was attempted on polypropylene and polyethylene materials with a beam 22 width of 2 mm and an aperture width 88 of 2 mm. The plastic melted into the aperture 84 leaving a slightly cratered surface.

An alternative to the channel 36, as shown in Figure 8, where cooling is provided to upper piece 26 via a vortex tube 48, moveable with the beam 22 along the surface of the overlying block 12. A column of gas 40a is blown from the tube 48 onto the surface of the component 26 to cool it, as the laser beam 22 is applied along the interface 30.

If required, the clamping apparatus 10 can also be moveable relative to the laser beam 22. A further embodiment of moveable clamping force using the vortex tube 48 is shown in Figure 9. The high-pressure gas 40 required to cool the surface of the upper component 26 can be directed through a nozzle 41, integral with the laser head 20, onto the upper component 26. The column of high-pressure gas 40a also acts as part of the support mechanism, forcing the upper component 26 and lower component 28 into intimate contact along the interface 30, in cooperation with the clamping device 18 and the supporting members 14 and 16. This process has been found to work well with pressures of 620 kPa or greater and on thin plastic components less than 4 mm thick.

In a further embodiment, shown in Figure 10, a wave guide effect of a plastic component 75 is used to direct the laser beam 22 to the interface 30, situated between the components 75 and 28. The laser beam 22 is focused on one end 78 of the component 75 and due to the higher index of refraction of the component 75, typically 1.5, over than of a surrounding medium 80, typically 1.0, the beam 22 experiences a total internal reflection 82 as it propagates down the component 75 to the interface 30. The component 28 is absorbent to the laser radiation to promote heating and welding of the components. This waveguide effect is best applied to highly transparent plastics with low light scattering properties such as acrylic, polycarbonate, and PMMA, in which the refractive index of the plastic component 75 is higher than that of the surrounding medium 80. These plastics can also be dyed with minimal effect on the transmission of the beam 22.

In another aspect of this embodiment, given in Figure 10, the wave guide effect 82 allows access of the laser beam 22 to the interface 30, in situations where the beam 22 cannot access the interface 30 directly.

An alternative to mechanical control of material absorption characteristics, through medium 40 cooling, split beams 66, or apertures 72, 84, is to modify the chemical components of the plastic material. Readily available pigment, such as carbon black, and dyes can be used for this purpose, however other colours may be used as well. Impact modifiers can also be added to the plastic material, where presence of these modifiers attenuates the laser radiation.

In each of the embodiments, the clamping blocks 12, 14 are made of a hard highly transparent material such as acrylic, polycarbonate, or other suitable scratch resistant materials that are substantially transparent to the laser radiation. The material of the clamping blocks 12, 14 should also be resilient in order to conform to the exterior surface of the weldable assembly 24. The thickness of the clamping blocks 12, 14 should normally be one half centimeter or more, in order for the blocks 12, 14 to have the rigidity necessary to force the mating surfaces 32, 34 into intimate contact, or abutment. The weldable components 26, 28 are typically made of thermoplastic material exhibiting dissimilar optical properties in the infrared spectrum, such as described above. The transparent upper component 26 and absorbent lower component 28 helps to localize the melting and subsequent welding of the mated surfaces 32 and 34.

The provision of transparent upper component 26 also facilitates control of the laser head 20 as shown in figure 12. The weld zone is monitored through the upper component 26 by an infrared detector 96. Detector 96 provides data to a microprocessor 98 that analyses the signal and adjusts the beam, 22 to maintain the weld conditions optimum. The detector operates at between 1000 nm and 5000 nm and may adjust the beam by interaction with power supply 100.

Although the invention has been described with reference to certain specific embodiments, various modifications thereof will be apparent to those skilled in the art without departing from the scope of the invention as outlined in the claims appended hereto.

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A system for welding a first component to a second component materially compatible with said first component by applying a beam of coherent radiation having a predetermined wavelength, the system comprising:
a support mechanism to hold said components together to provide an interface between said components, at least part of said support mechanism substantially transparent to said predetermined wavelength; a laser apparatus positionable with respect to said components to cause said beam to be transmitted along an optical path substantially transparent to said predetermined wavelength through said part of said support mechanism and through one of said components to impinge on said interface; and an intermediate layer adjacent to said interface being absorbent to said predetermined wavelength, said intermediate layer being either a separate layer or said intermediate layer being an integral layer with one of said components, wherein said beam being of sufficient intensity and focused to melt a portion of each of said components at said interface; whereby upon cooling, said components become welded to one another.

2. A system for welding according to claim 1, wherein said support mechanism comprises a pair of blocks movable to relative to one another between an open position and a closed position.

3. A system for welding according to claim 2, wherein at least one of said blocks further including a passageway for directing a cooling medium to provide localized cooling in a region of said optical path to inhibit degradation by said beam of a portion of said block adjacent to passageway.

4. A system for welding according to claim 3, wherein said passageway is located between an exterior surface of said block and an exterior surface of said components for inhibiting degradation by said beam of a portion of said components adjacent to said passageway.

5. A system for welding according to claims 3 or 4, wherein said cooling medium is a chemically inert gas to inhibit oxidation of said portion.

6. A system for welding according to claim 5, wherein said gas is nitrogen.

7. A system for welding according to claim 2, wherein an opposing face of one of said blocks is contoured to be complementary to at least a portion of an adjacent exterior surface of one of said components.

8. A system for welding according to claim 7, wherein one of said blocks has a substantially uniform a thickness and a radius of curvature to inhibit variability in the intensity of said beam when transmitted through said one of said blocks.

9. A system for welding according to claim 2, wherein a thickness of one of said blocks is substantially uniform to inhibit variability in the intensity of said beam when transmitted through said one of said blocks.

10. A system for welding according to claim 7, wherein said blocks are composed of a resilient material capable of conforming said components to a contoured form of said blocks.

11. A system for welding according to claim 2, wherein said predetermined wavelength of said beam is in the range of 500nm to 1060nm.

12. A system for welding according to claim 11, wherein a material substantially transparent to said predetermined wavelength of at least one of said pair of said blocks is selected from the group comprising acrylic, polycarbonate, and PMMA.

13. A system for welding according to claim 1, wherein said first component is substantially transparent to said predetermined wavelength to provide said optical path and said second component is substantially absorbent to said predetermined wavelength to provide said intermediate layer.

14. A system for welding according to claim 1 further including an aperture formed in said first component for providing said optical path and said second component being substantially absorbent to said predetermined wavelength to provide said intermediate layer.

15. A system for welding according to claim 14, wherein said aperture having a generally triangular shaped cross-section.

16. A system for welding according to claim 14, wherein said aperture having a generally cone shaped cross-section.

17. A system for welding according to claims 15 or 16, wherein a width at one end of said aperture is less than 2mm.

18. A system for welding according to claim 1, wherein absorbency characteristics to said predetermined wavelength of at least one of said components is modified by an addition of pigments or dyes.

19. A system for welding according to claim 18, wherein a composition of said pigments or dyes comprises a mixture of primary colors.

20. A system for welding according to claim 19, wherein said mixture is both substantially absorbent to a wavelength of visible light and substantially transparent to said predetermined wavelength of said beam.

21. A system for welding according to claim 1, wherein absorbency characteristics to said predetermined wavelength of at least one of said components is modified by an addition of an impact modifier.

22. A system for welding according to claim 1, wherein one of said components comprising an elastomeric material.

23. A system for welding according to claim 22, wherein said elastomeric material is a gasket.

24. A system for welding according to claim 1, wherein said support mechanism comprises a frame for supporting said components and a high pressure fluid source for impacting an exterior service of said components with a fluid stream in order to maintain said oppositely directed surfaces in abutment.

25. A system for welding according to claim 24, wherein said fluid stream provides localized cooling of said components in order to inhibit degradation of said components by said beam.

26. A system for welding according to claims 24 or 25 further comprising a nozzle for directing a fluid stream, wherein said nozzle is displaceable relative to said frame.

27. A system for welding according to claim 26, wherein said nozzle is coupled to said laser apparatus.

28. A system for welding according to claim 1, wherein said beam further comprising a first beam and a second beam impingeable at different locations on a surface of said components.

29. A system for welding according to claim 28, wherein said first beam and second beam are focused to impinge on said interface at a common focal region.

30. A system for welding according to claim 28 further comprising a beam splitter for splitting said beams into said first beam and said second beam.

31. A system for welding according to claim 28, wherein an angle between said beams and said surface is greater than 15° to inhibit reflection losses of said beams.

32. A system for welding according to claim 1, wherein one of said components is a wave guide for propagating said beam to said interface.

33. A system for welding according to claim 32, wherein said wave guide comprises a substantially transparent plastic material.

34. A system for welding according to claim 33, wherein said wave length has minimal light scattering properties and is selected from the group comprising acrylic, polycarbonate, and PMMA.

35. A system for welding according to claim 1, wherein said components when placed in abutment comprise a plurality of exterior walls to define an interior.

36. A system for welding according to claim 35 further comprising a pressure device coupled to said components for regulating a supply of pressurizing medium to inhibit flexure of said exterior walls when said components are placed in said support mechanism.

37. A system for welding according to claim 36, wherein a sealant is interposed between said components at said interface for inhibiting a transfer of said pressurizing medium through said interface.

38. A system for welding according to claim 1 further comprising a detector positioned adjacent to said components for monitoring a property of said weld zone.

39. A system for welding according to claim 38, wherein said detector providing data for adjusting said beam to maintain weld conditions at a preselected level.

40. A system for welding according to claims 38 or 39, wherein said detector is an infrared detector.

41. A system for welding by a beam of coherent radiation a first component to a second component materially compatible with said first component, at least one of said components being substantially transparent to a predetermined wavelength of said beam, the system comprising:
a support mechanism for locating said components with oppositely directed surfaces to provide an interface between said components, at least part of said support mechanism substantially transparent to said predetermined wavelength;

an intermediate layer absorbent to said predetermined wavelength interposed between said oppositely directed surfaces of said first component and second component; and a laser apparatus positionable with respect to said components to cause said beam to be transmitted along an optical path substantially transparent to said predetermined wavelength through said part of said support mechanism and said first component to impinge on said intermediate layer, said beam being of sufficient intensity and focused to produce a melt zone consisting of a portion of each of said components at said interface; whereby upon cooling, said components become welded to one another.

42. A system for welding according to claim 41, wherein said intermediate layer is a plastic film.

43. A system for welding according to claim 41, wherein said intermediate layer is a liquid.

44. A system for welding according to claim 41, wherein said intermediate layer is a paste.

45. A clamping mechanism operable between an open position and a closed position for positioning a pair of components with oppositely directed surfaces in abutment to provide an interface between said pair of components, said components to be welded at said interface by a beam of coherent radiation, the mechanism comprising:
a first portion for locating said components; and a second portion displaceable relative to said first portion for biasing said components into contact at said interface; wherein at least part of said portions is substantially transparent to a predetermined wavelength of said beam for facilitating transmission of said beam through said portions to impinge upon said interface.

46. A clamping mechanism according to claim 45, wherein said portions are a pair of blocks.

47. A clamping mechanism according to claim 46, wherein at least one of said blocks further including a passageway for directing a cooling medium to provide localized

cooling in order to inhibit degradation by said beam of a portion of said block adjacent to said passageway.

48. A clamping mechanism according to claim 47, wherein said passageway is located between an exterior surface of said block and an exterior surface of said components for inhibiting degradation by said beam of a portion of said components adjacent to said passageway.

49. A clamping mechanism according to claim 46, wherein an opposing face of one of said blocks has a contoured form complementary to at least a portion of an adjacent exterior surface of one of said components.

50. A clamping mechanism according to claim 49, wherein a thickness and a radius of curvature of said one of said blocks are substantially uniform to inhibit variability in the intensity of said beam when transmitted through said one of said blocks.

51. A clamping mechanism according to claim 46, wherein a thickness of one of said blocks is substantially uniform to inhibit variability in the intensity of said beams when transmitted through said one of said blocks.

52. A clamping mechanism according to claim 49, wherein said blocks are composed of a resilient material capable of conforming said components to said contoured form of said blocks.

53. A clamping mechanism according to claim 45, wherein said portions further comprising a frame for supporting said components and a fluid stream delivered by a high pressure fluid source, said fluid stream for impacting an exterior surface of said components in order to maintain said oppositely directed surfaces in abutment.

54. The clamping mechanism according to claim 53, further comprising a nozzle for directing said fluid stream, wherein said nozzle is displaceable relative to said frame.

55. A method for welding a first component to a second component materially compatible with said first component by a beam of coherent radiation having a predetermined wavelength, the method comprising the steps of:
positioning said components with oppositely directed surfaces in abutment to provide an interface between said components; maintaining a position of said components by a support mechanism having at least a part substantially transparent to said predetermined wavelength; transmitting said beam produced by a laser apparatus along an optical path substantially transparent to said predetermined wavelength through said part and through at least one of said components; impinging of said beam on said interface, said interface having an adjacent intermediate layer being absorbent to said predetermined wavelength, said intermediate layer being either a separate layer or said intermediate layer being an integral layer with one of said components; melting a portion of each of said components at said interface; and cooling said components so that said components become welded to one another.

56. A method according to claim 55 further comprising the step of directing a cooling medium through a passageway in said support mechanism to cool a portion of said support mechanism for inhibiting degradation thereof.

57. A method for welding according to claim 55 further comprising the step of directing a cooling medium over a surface of said components for inhibiting degradation by said beam of a portion of said components.

58. A method for welding according to claims 56 or 57 further comprising the step of using a chemically inert gas as said cooling medium.

59. A method for welding according to claim 55 further comprising a step of impinging a first beam and a second beam at said predetermined wavelength at different locations on a surface of said components.

60. A method for welding according to claim 59 further comprising the step of focusing said first beam and said second beam at a common focal region on said interface.

61. A method for welding according to claim 55, wherein an aperture is formed in said first component for providing said optical path and said second component being substantially absorbent to said predetermined wavelength.

62. A method for welding according to claim 61 further comprising the step of defocusing said beam to cause a wall of said aperture to melt, thereby collapsing said aperture to form said melt zone.

63. A method for welding according to claim 55 further comprising the step of monitoring a pressure of an interior defined by a plurality of exterior walls formed by the assembly of said components.

64. A method for welding according to claim 63 further comprising the step of regulating a supply of pressurizing medium for said interior to inhibit flexure of said exterior walls.

65. A method for welding according to claim 64 further comprising the step of interposing a sealant between said components at said interface for inhibiting a transfer of pressurizing medium through said interface.

66. A method for welding according to claim 55 further comprising the step of monitoring a property of said weld zone by a detector.

67. A method for welding according to claim 66 further comprising the step of adjusting said beam in response to data supplied by said detector to maintain weld conditions at a preselected level.

68. A method for welding according to claims 66 or 67, wherein said detector is an infrared detector.

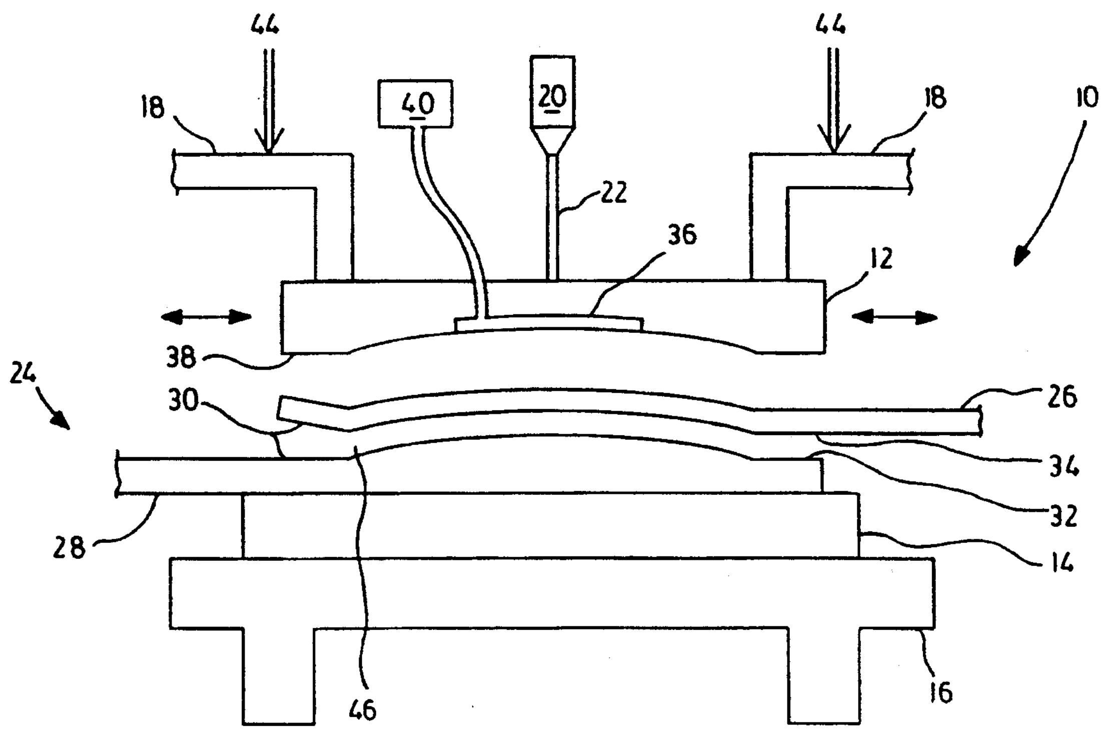


FIG. 1

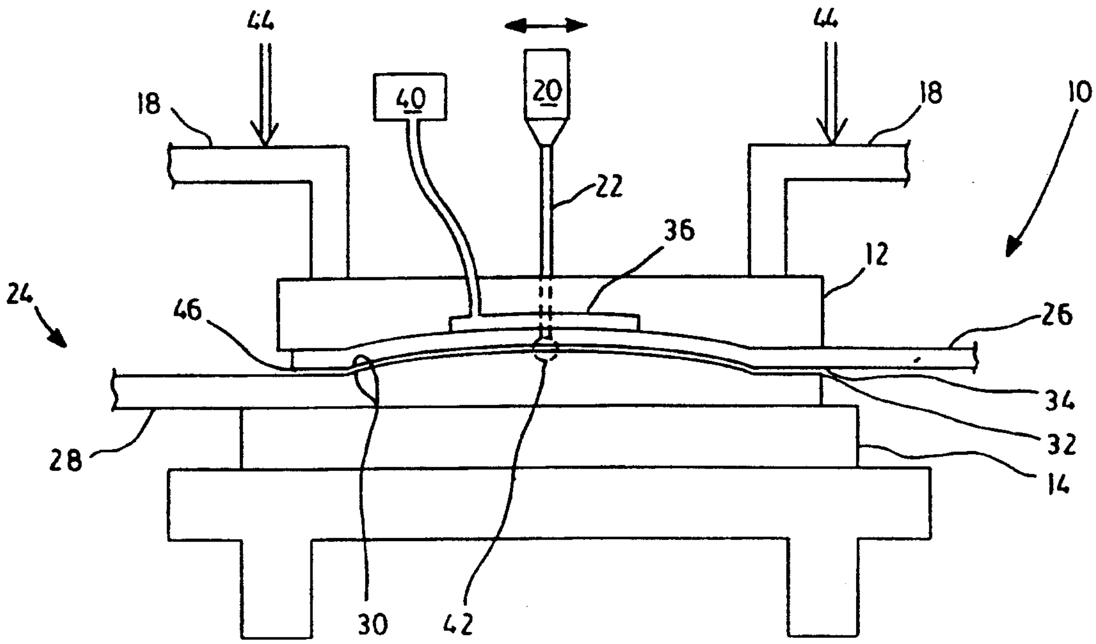


FIG. 2

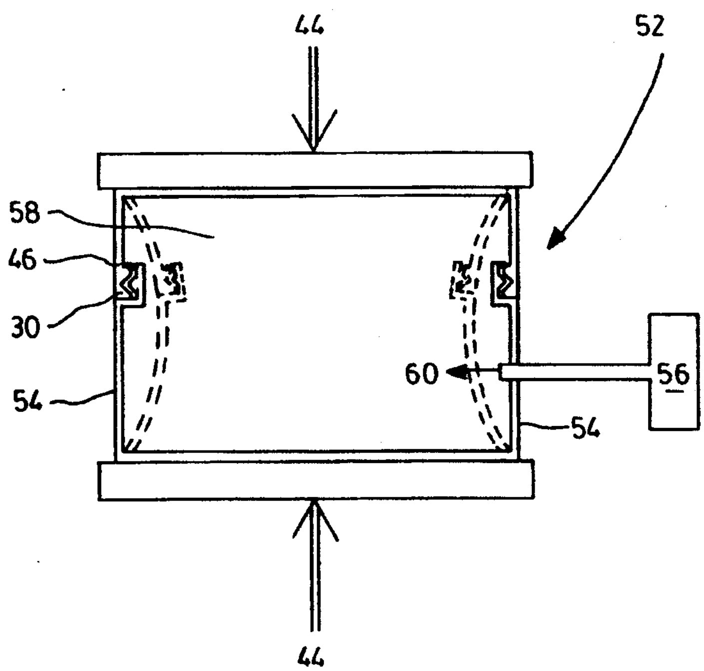


FIG. 3

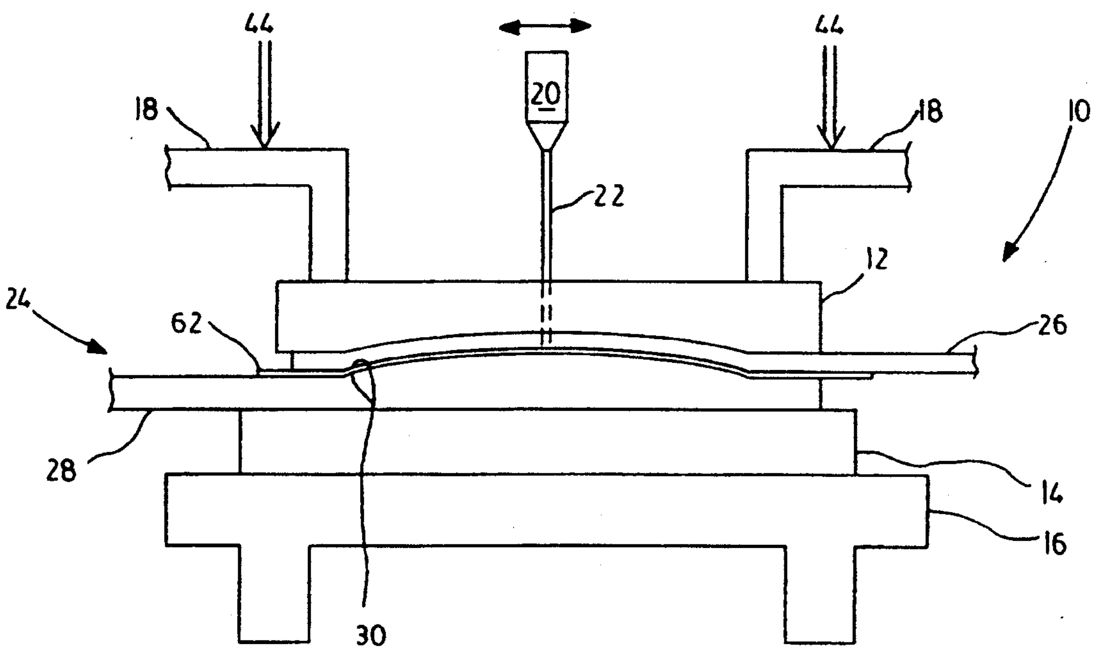


FIG. 4

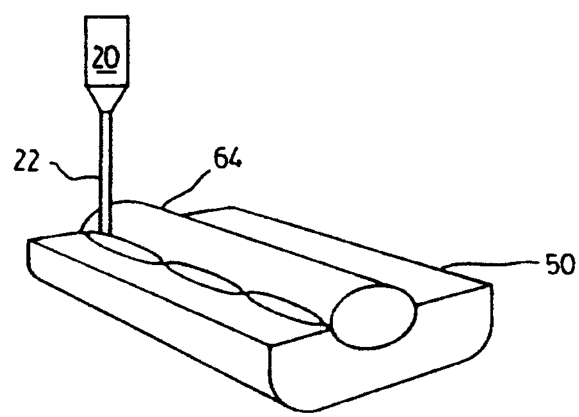
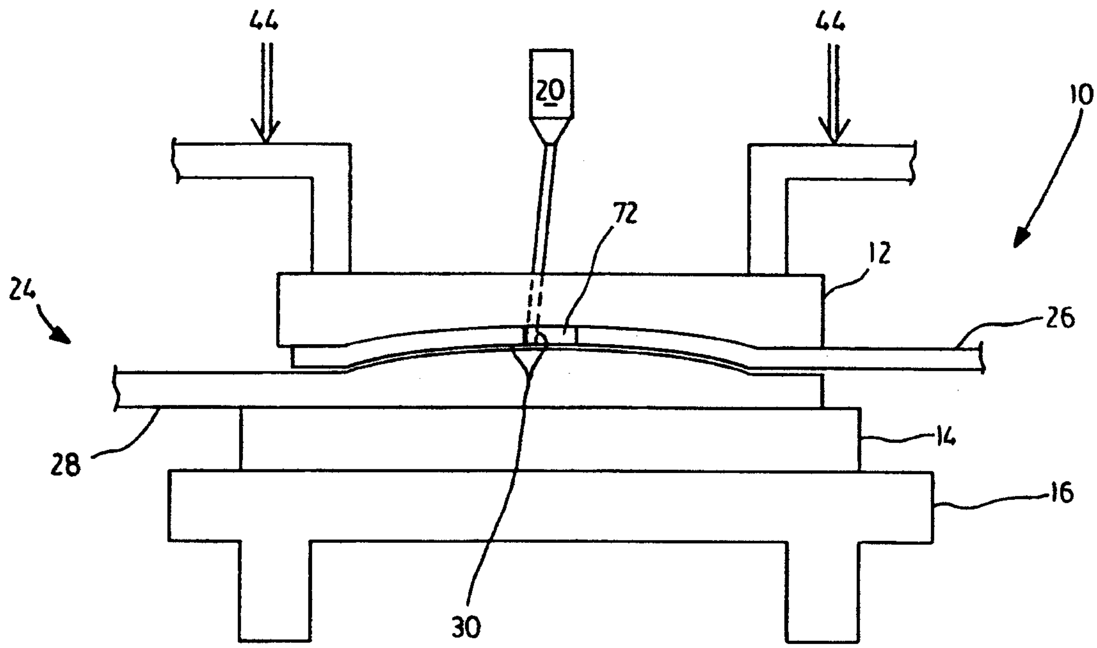
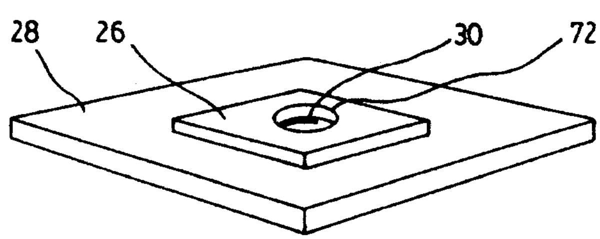


FIG. 4a



a



b

FIG. 5

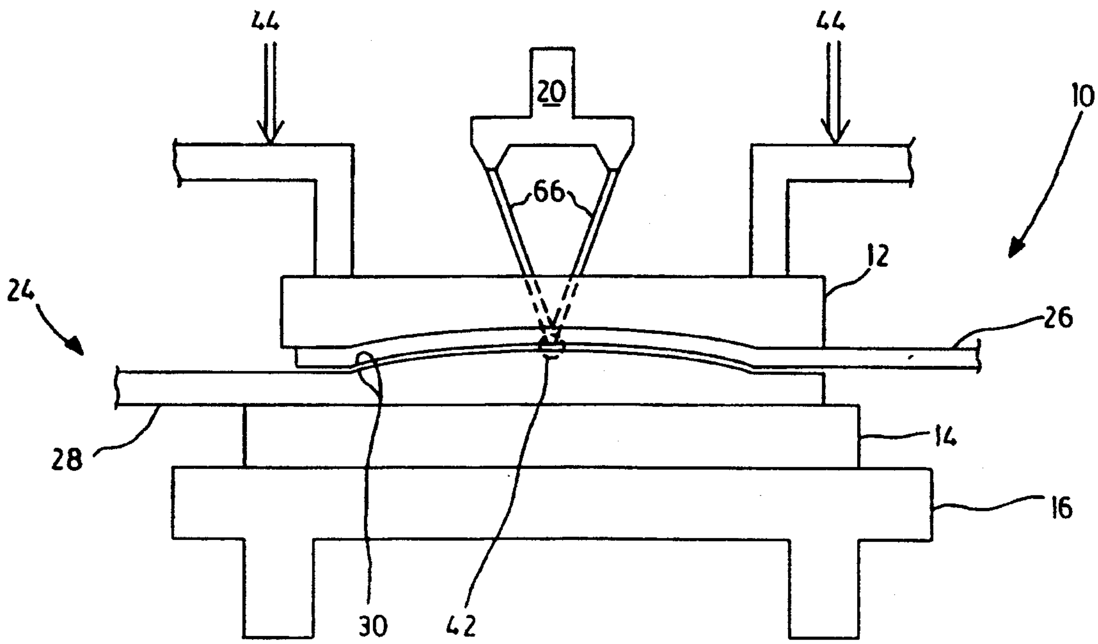
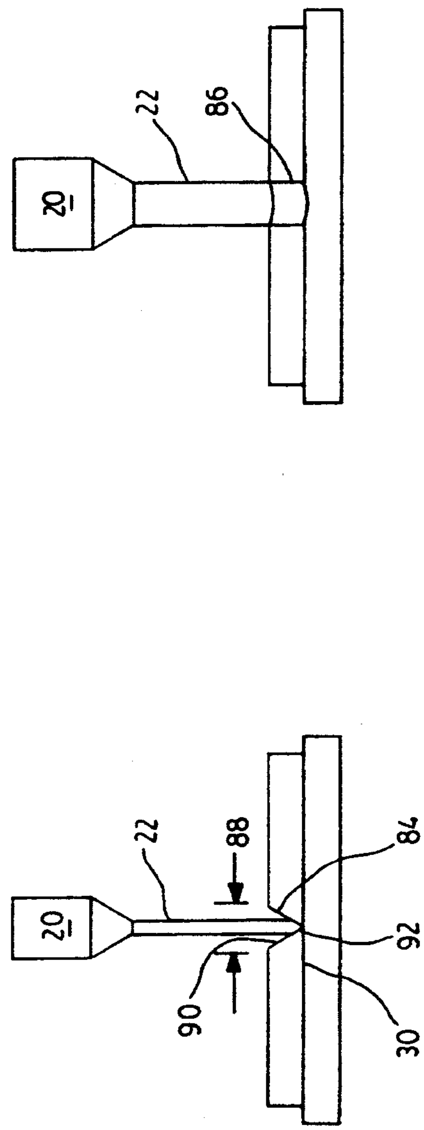


FIG. 6



b

a

FIG. 7

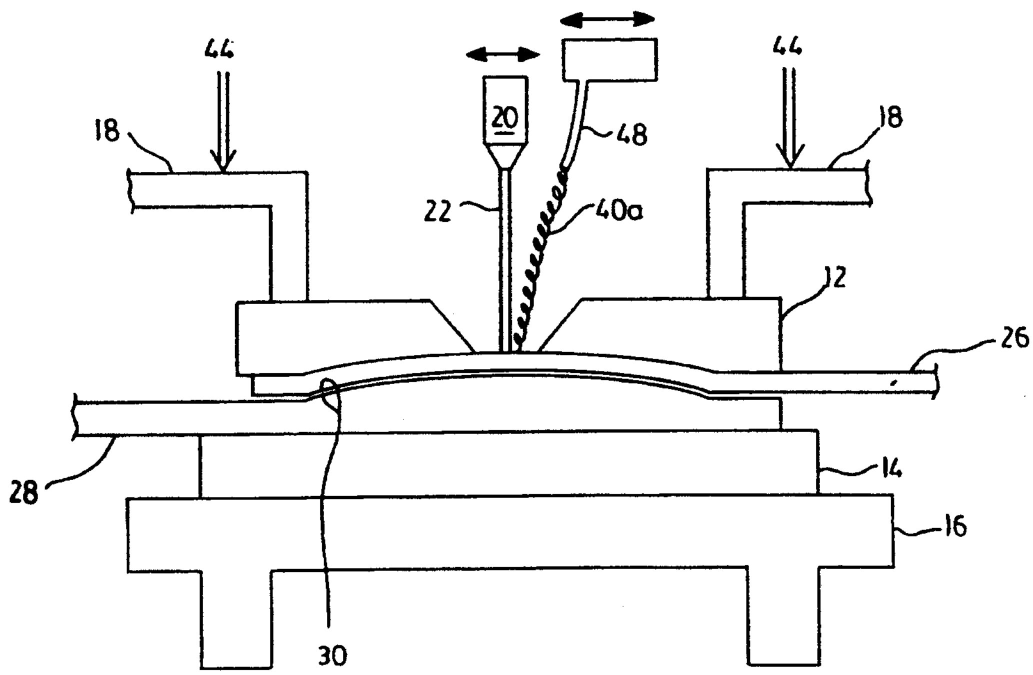


FIG. 8

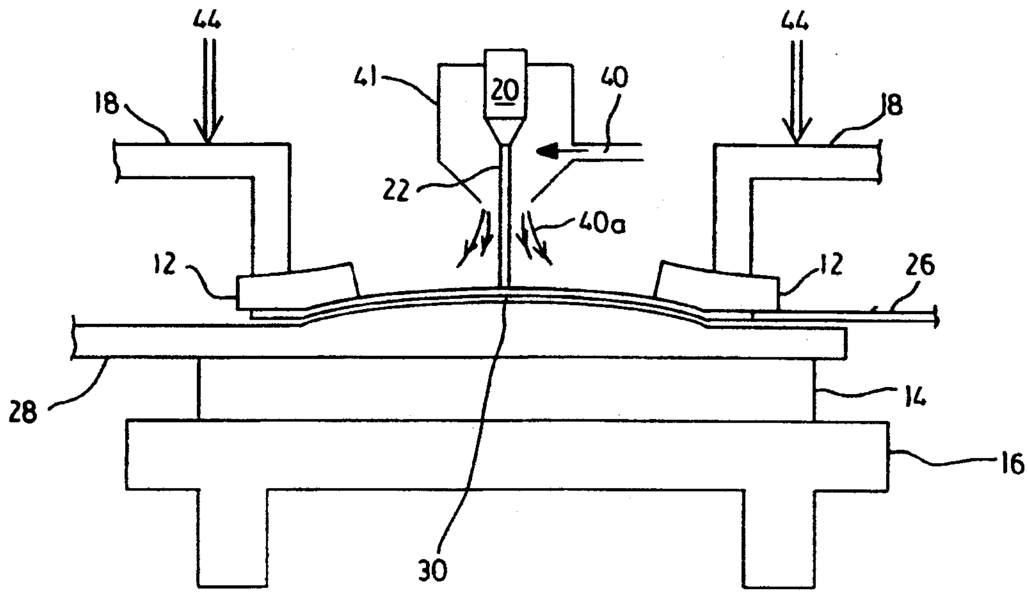


FIG. 9

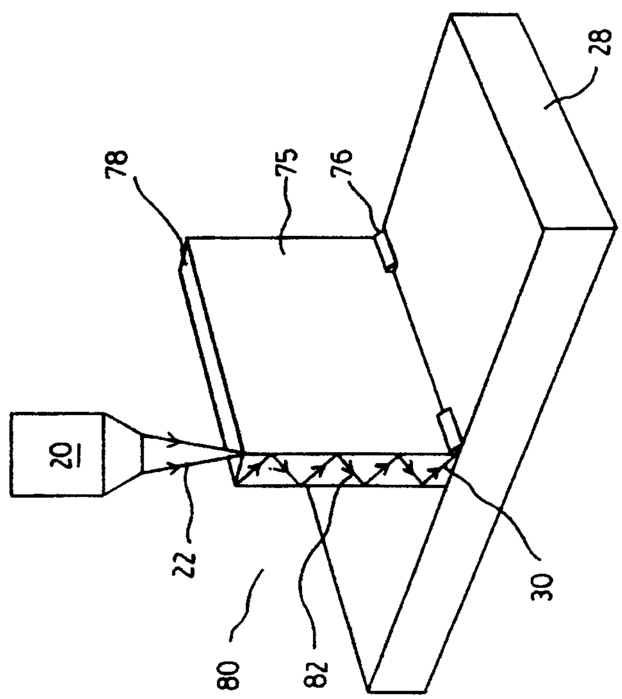


FIG. 10

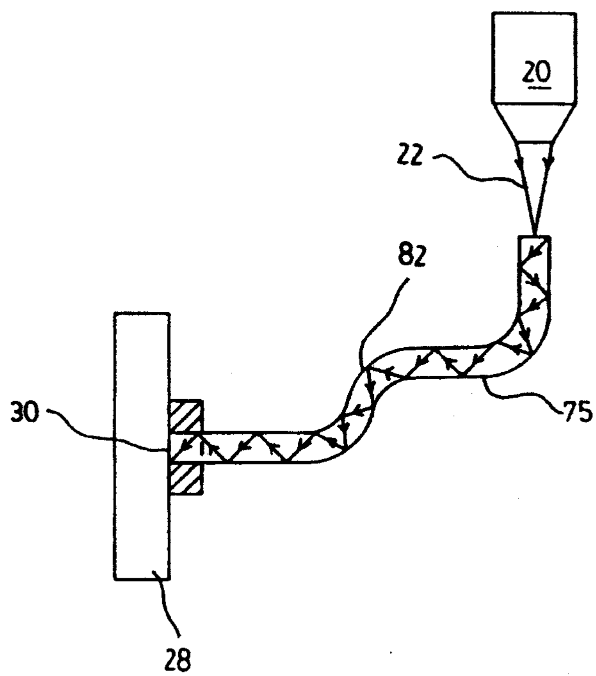


FIG. 11

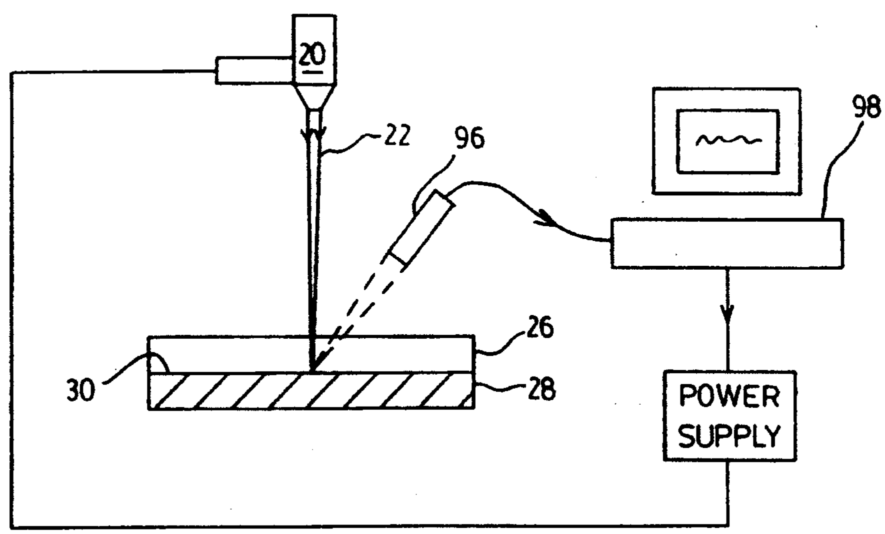


FIG. 12

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(19) World Intellectual Property Organization
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(71) Applicant *(for all designated States except US)*: **POWER-LASERS LTD.** [CA/CA]; Advanced Technology Centre, 543 Mill Street, Units 2 & 3, Kitchener, Ontario N2G 2Y5 (CA).

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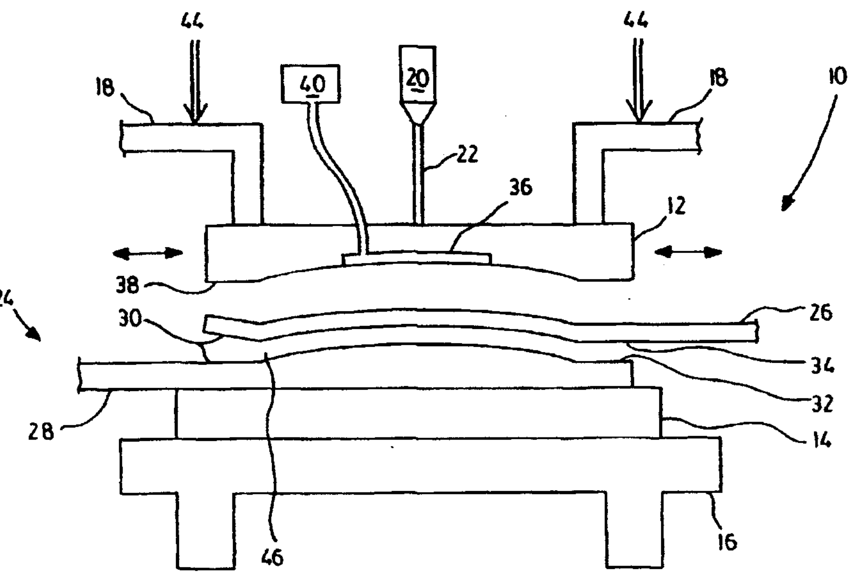
(81) Designated States *(national)*: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:
— *With international search report.*

[Continued on next page]

(54) Title: METHOD OF CLAMPING THERMOPLASTIC PIECES AND HEAT CONTROL FOR LASER WELDING



(57) Abstract: Plastic pieces (26, 28) for laser welding are clamped by a support mechanism (12, 14) that covers an interface of a joint to be welded. The support mechanism is transparent to the laser (20) radiation. Surface cooling (40) of the support mechanism and the pieces is provided by fluid such as nitrogen directed to the point of laser impingement at the interface. The local intensity of the laser can be reduced by beam splitting. Heating at the weld zone is controlled by the differing optical characteristics of the components. One of the pieces can be used as a waveguide to direct the laser radiation to the interface.

WO 00/66345 A3

(88) **Date of publication of the international search report:** 26 April 2001

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

INTERNATIONAL SEARCH REPORT

Intern. ...al Application No
PCT/CA 00/00458

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 B29C65/16 B23K26/12

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 B29C B23K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PUETZ H ET AL: "LASER WELDING OFFERS ARRAY OF ASSEMBLY ADVANTAGES" MODERN PLASTICS INTERNATIONAL,CH,MCGRAW-HILL,INC. LAUSANNE, vol. 27, no. 9, 1 September 1997 (1997-09-01), pages 127-128,130, XP000699142 ISSN: 0026-8283	1,2, 11-13, 18-20, 38-40, 45,46, 55,66-68
Y	the whole document	3-6,21, 41-44, 47,48, 56,57

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
13 October 2000	28. 12. 00

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	CORDENIER J.

1

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	FR 1 436 130 A (SOCONY MOBIL OIL COMPANY INC) 1 July 1966 (1966-07-01) page 7, right-hand column, line 17 - line 19; claims 1,2,4; figures	1,2,9, 21,45, 46,51
Y	DE 41 35 782 A (MITSUBISHI ELECTRIC CORP) 21 May 1992 (1992-05-21)	3-6,47, 48,56,57
A	column 4, line 47 - line 56; figures 1,2	2,46
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Y	FR 1 577 304 A (HELLER) 8 August 1969 (1969-08-08) page 5, right-hand column, line 35 - line 58 page 6, left-hand column, line 13	21,41-44
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P,X	EP 0 942 139 A (THERMOFORM AS) 15 September 1999 (1999-09-15) column 4, line 22 - line 26; figure 2B	1,2,9, 13,45, 46,51,55
P,Y	WO 00 20157 A (JONES IAN ANTHONY ;WISE ROGER JEREMY (GB); WELDING INST (GB)) 13 April 2000 (2000-04-13) the whole document	41-44

1

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CA 00/00458

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-6,9, 11-13, 18-21, 38-48, 51, 55, 56, 66-68

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. Claims: 1,2,3,4,5,6,9,11,12,13,18,19,20,21,38,39,40,41,42, 43,44,45,46,47,48,51,55,56,66,67,68

   Transparent clamping mechanism including a passage way for a cooling medium

   1.1. Claims: 9,51
   pressure block of uniform thickness

   1.2. Claim : 12
   transparent pressure block made of acrylic,polycarbonate,pmma

   1.3. Claims: 18,19,20
   Modification of absorbency characteristics of the components by additions of pigments or dyes

   1.4. Claim : 21
   Use of an impact modifier

   1.5. Claims: 38,39,40,66,67,68
   Welding process control

2. Claims: 7,8,10,49,50,52

   Contoured pressing block

3. Claims: 14,15,16,17,61,62

   Providing one of the components to be laser welded with an aperture to have access to the second component.

4. Claims: 22,23

   Laser welding of an elastomeric material

5. Claims: 24,26,27,53

   Applying a high fluid pressure to the components in order to bring them in abutment

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

6. Claims: 28,29,30,31,59,60

   Use of a first and second laser beam at different or common locations

7. Claims: 32,33,34

   Use of one of the components as a wave guide

8. Claims: 35,36,37,63,64,65

   Internaly pressurizing a hollow article during welding

Please note that all inventions mentioned under item 1, although not necessarily linked by a common inventive concept, could be searched without effort justifying an additional fee.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/CA 00/00458

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